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# NESTING SUCCESS IN FLORIDA SANDHILL CRANES

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ABSTRACT.—Through aerial surveys in 1988 and 1989, 111 Florida Sandhill Crane (*Grus canadensis pratensis*) nests were found on a 60-km$^2$ site in northern Polk County, Florida. Mean laying dates were 7 March in 1988 and 25 February in 1989. Overall hatching success was 59% using the Mayfield method; however, recruitment was only 5% in both years. Causes of nest failure included predation, flooding, abandonment, and egg infertility and addling, but the cause of 45% of the failures was unknown. Nesting cranes seemed to habituate to certain forms of human disturbance and nested within 400 m of highways, railroads, and mines; cranes also were tolerant of helicopter flyovers. Even so, investigator visits to nests and development-induced alterations of surface water drainage were implicated in 24% of the nest failures. *Received 24 April 1991, accepted 1 July 1991.*

Most studies of nesting success of Sandhill Cranes (*Grus canadensis*) have involved periodic searches for active nests, with subsequent monitoring of the nest contents (e.g., Thompson 1970, Valentine 1982, Walkinshaw 1982, Bennett and Bennett 1990). The Mayfield (1961, 1975) method is well suited for such studies since most nests are found after initiation or the laying of the first egg. This method reduces the bias associated with the lower probability of finding unsuccessful nests, which are shorter-lived than those that hatch successfully (Miller and Johnson 1978, Klett and Johnson 1982). No published accounts of Sandhill Crane nesting success have included this method to determine hatching success.

We here present data on nest success of the Florida Sandhill Crane (*G. c. pratensis*), a threatened species in Florida (FGFWFC 1974). We also assess the impact of human disturbance, including highways, mining, and nest visits by the investigators, on a local crane population in an effort to improve management decisions regarding the conservation of this species.

## STUDY AREA

The study site (60 km$^2$) was located in northwestern Polk County, Florida, approximately 50 km southwest of Orlando in a wetland system known regionally as the Green Swamp. The study area consisted of a mosaic of cypress (*Taxodium ascendens*) and bay (*Gordonia lasianthus, Persea palustris, Magnolia virginiana*) swamps, herbaceous marsh, pine (*Pinus palustris, P. elliottii*) flatwoods, scrub oak (*Quercus* spp.), orange groves, and improved pasture (predominantly *Paspalum notatum*) with scattered oak and pine. Palustrine wetlands accounted for 48% of the total study area, more than half of which wetlands were forested. Marsh habitats included seasonally flooded aquatic bed, emergent, and shrub-scrub wetlands (Cowardin et al. 1979). Elevation varied between 40–47 m above sea level. Sources of human

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disturbance to nesting included an interstate highway (I-4) and a 100-ha sand mine. The subtropical climate of the area consists of wet, hot summers and moist, cool winters. Hurricanes may affect summer and fall weather, while relatively little rain falls during spring. August and September, the wettest months, average 184 mm of rain/month, while November and December, the driest months, average 50 mm/month. The 30-year mean January and July temperatures are 15.3°C and 27.6°C, respectively; the annual average temperature is 22°C (NOAA 1990).

## METHODS

We systematically surveyed the study area for nests weekly from 13 January through 18 May 1988 from a helicopter flying 40–90 m above ground. In 1989, surveys were flown from 3 January to 25 April by helicopter and by fixed-wing aircraft flying at 50–150 m above ground. Surveys concentrated on marsh habitat. Active nests, defined as those containing eggs or an incubating adult, were obvious from the air. During each flight we plotted nest locations on aerial photographs. We observed nests every 2–10 days in one of three ways: via helicopter or fixed-wing aircraft overflights, from an elevated vantage point (e.g., tree, ladder, truck, or from a >40 m-distance on the ground), or by approaching on foot, thereby flushing the incubating bird ("nest visit"). During each nest visit, we recorded the location, date, nest contents, incubation stage, water levels 1 m from nest edge, and presence of adults in the area.

Eggs were floated in warm (44°C) iodinized water to determine their age (Westerskov 1950). Newly laid crane eggs lie horizontally on the bottom of the water container, whereas eggs more than 15 days old float with the blunt end about 1 cm above the water's surface. Imitating an adult crane's brood call usually elicited a visible or audible response from the chick within a well-developed egg.

We monitored nests more closely during the expected hatching period so that the fate of eggs could be verified. For successful nests, we calculated date of initiation by subtracting the 30-day mean incubation period (Walkinshaw 1976, 1981, 1982) from the hatch date. Fourteen nests visible from a distance throughout the incubation period were not visited ("undisturbed nests") and were used for comparison with visited nests.

To avoid adverse heating and cooling of eggs during nest visits, we spent less than 5 min at each nest and visited nests from 07:00 to 11:00 h or from 16:00 to 17:00 h; we avoided visiting nests during extremely cool or warm weather or if rain was expected. Because flushing cranes sometimes crack eggs (Valentine 1982), we made noisy approaches to avoid surprising incubating birds.

Since cranes have precocial young, nesting efforts were defined as successful if at least one egg hatched. Evidence for nest success included direct observation of one or two chicks, peeping or pipping eggs, or a combination of length of nesting activity at the site together with the presence of eggshell fragments with detached membranes in the nest bowl. If a nesting effort ended before the eggs were aged and none of the above was observed, the outcome was considered unknown, and the nest was excluded from our analysis of nesting success. To determine nesting success, we employed the traditional (successful nests/all nests) and Mayfield (1961, 1975) methods. The assumption of constant daily mortality, central to the Mayfield method, was tested by dividing the incubation period into three 10-day intervals (early, middle, and late) and calculating mortality rates for each of these stages of incubation; a Bonferroni multiple comparison test was used to compare these rates. We used the $Z$-statistic to test differences between nesting success estimates (see Hensler and Nichols 1981 for derivations). Renesting within the same breeding season was determined based on the location of nests and knowledge of territorial pairs and the fate of their previous nest.

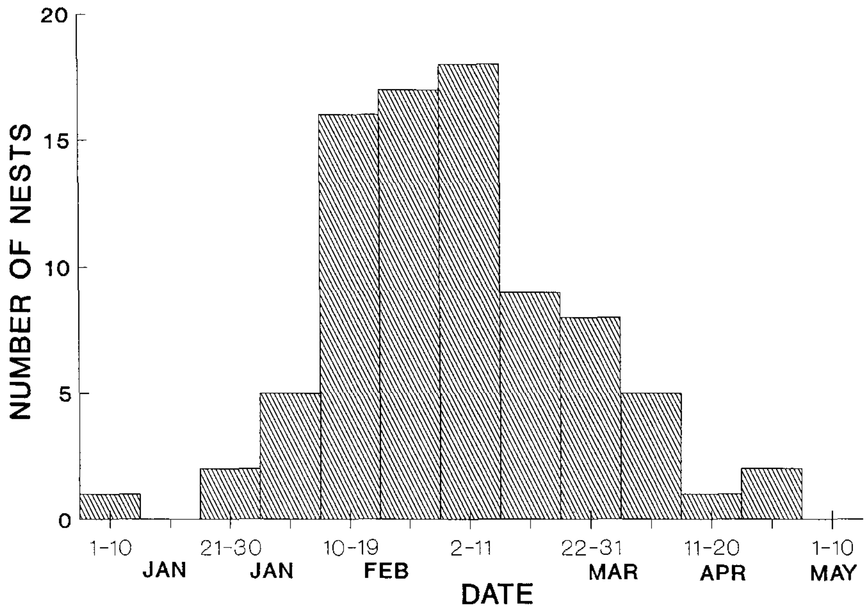


FIG. 1. Initiation dates of 84 Florida Sandhill Crane nests, northwestern Polk County, Florida, 1988 and 1989.

We used both first nests and renests when calculating nesting success statistics. We marked terminated nests with a length of plastic pipe so that we could compare them with subsequent nest locations.

We used evidence remaining at or near the nest to determine which predators affected nesting success (Rearden 1951). We monitored water levels to confirm flooding as a cause of nest failure. Water gauges in 16 wetlands distributed throughout the study area were read every 3–14 days; large marshes contained 4 or 5 gauges as replicates.

In July and August of both years, fledging and recruitment rates were estimated as the percentage of fledglings in roosting flocks of Florida Sandhill Cranes on the study area. We also observed less gregarious pairs or families to help assess the accuracy of ratios in flocks.

## RESULTS

*Nest distribution and chronology.*—Fifty nests were discovered an average of 5.3 ± 0.9 (SE) days after the initiation of egg laying in 1988. In 1989, we found 61 nests an average of 11.0 ± 1.2 days after egg laying, when the average time between surveys was 10.0 ± 0.7 days, compared to 8.0 ± 1.0 days in 1988. In both years mean and median initiation dates were 3 March and 1 March, respectively (Fig. 1). Nests were initiated as early as 2 January (1988) and as late as 22 April (1988). Simultaneously active nests were as close as 72 m. Based on 21 territories that were

TABLE 1

SUCCESS RATE OF 111 FLORIDA SANDHILL CRANE NESTS FOUND IN NORTHWESTERN POLK COUNTY, FLORIDA

| | 1988 | 1989 |
|---|---|---|
| N | 47 | 55 |
| Unknown | 3 | 6 |
| Hatch | 66% | 69% |
| Mayfield | 59% | 59% |

assumed to be permanent year-round, pairs nested an average of 124 m (SE = 17.0, range = 8–294) from nest locations of the previous year.

Cranes using wetlands larger than 50 ha nested significantly later ($\bar{x}$ = 59.8 ± 2.3 Julian date, N = 37) than those nesting in wetlands of less than 50 ha ($\bar{x}$ = 53.6 ± 2.9 Julian date, N = 43, $Z$ = 6.8, $P$ = 0.001). Migrant Greater Sandhill Cranes (*G. c. tabida*) tended to use the larger marshes for foraging.

*Hatching success.*—Of 102 nests with known outcomes, 69 (68%) hatched at least one chick (Table 1). The Mayfield (1961, 1975) method for calculating nesting success resulted in lower estimates (Table 1). We found no significant differences in mortality rates among early, middle, and late incubation stages ($Z = 0.6$, $P > 0.05$).

Modal clutch size was two eggs ($\bar{x}$ = 1.81). However, 14% (6) and 24% (12) of nests had one-egg clutches in 1988 and 1989, respectively, with a combined success rate of 78%. Nest and egg productivity values were similar between years (Table 2). Of the 75 two-egg clutches with known fate, 53% hatched both eggs, while only one of the eggs hatched in 16% (12) of these nests.

TABLE 2

PRODUCTIVITY, ASSESSED AT THE HATCHLING STAGE, OF FLORIDA SANDHILL CRANE NESTS AND EGGS IN NORTHWESTERN POLK COUNTY, FLORIDA

| | 1988 | 1989 | 1988/1989 |
|---|---|---|---|
| Young per egg laid | 0.63 | 0.67 | 0.65 |
| Young per nest | 1.06 | 1.04 | 1.05 |
| Young per successful nest[a] | 1.61 | 1.50 | 1.55 |

[a] A nest hatching at least one egg.

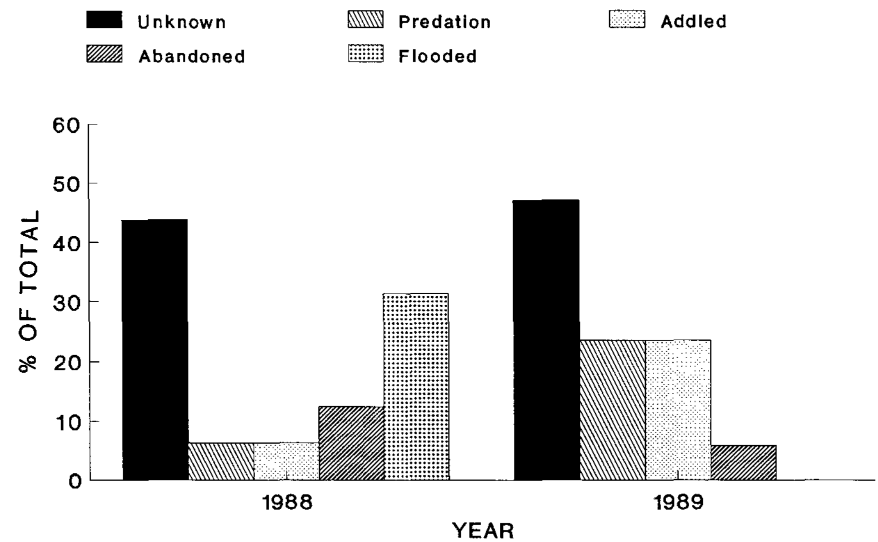


FIG. 2. Suspected causes of nest failure at Florida Sandhill Crane nests in 1988 (N = 16) and 1989 (N = 17), northwestern Polk County, Florida.

Causes of nest failure included predation, flooding, abandonment, and egg infertility and addling (Fig. 2). We often had difficulty ascertaining the exact causes of nest failure, and 15 of the 33 nest failures (45%) were the result of unknown causes. In 1988, the greatest proportion of nest failures (30%, N = 5) was due to flooding between 12 and 22 March. During this period two major rain events rapidly increased average water levels within the wetlands from 15 to 30 cm during this time.

No nests failed due to flooding in 1989; however, nest failures in that year due to addled or infertile eggs and predation were approximately four times as great as in 1988. Although we were unable to identify any predation to species, egg predators common in the area were raccoons (*Procyon lotor*) and Fish Crows (*Corvus ossifragus*). Other nest and chick predators observed on the study area included feral pig (*Sus scrofa*), American alligator (*Alligator mississippiensis*), river otter (*Lutra canadensis*), bobcat (*Lynx rufus*), Red-tailed Hawk (*Buteo jamaicensis*), and Great Horned Owl (*Bubo virginianus*). We observed a Red-tailed Hawk stooping on a pair of cranes and their day-old chick on 25 March 1988.

The three nests that failed due to abandonment during our study probably were associated directly or indirectly to our approach and handling of the eggs and nests during incubation. We attempted to mark a pair of attending adult cranes by securing a sponge saturated with leather dye in their nest. On the subsequent visit, 9 days later, the eggs were cold and no adults were present.

*Chick recruitment.*—Based on flock counts in July and August of over 100 communally roosting birds, we found that young-of-the-year represented only 5% of the local population in both years. Apparently, both members of a brood seldom survived. We observed a pair of adults with two nearly fledged chicks on the study site only once each year.

*Renesting.*—We estimated that 21% of the 111 total nesting attempts were second efforts. Distances between first nestings and presumed renestings averaged 183 ± 62 m, which was closer than the average distance between simultaneously active adjacent nests ($\bar{x}$ = 277 ± 65 m) in the most densely populated marsh. One nest was used twice during the 1988 nesting season.

*Human disturbance factors.*—Cranes flushed when we were from 3 to 75 m from the nest. Once flushed, the birds remained off the nest for 15 min to at least 3 h.

During surveys, incubating cranes remained on their eggs in 82% (N = 259) of the cases in which the helicopter flew as low as 40 m above them; incubating cranes never flew from the nest during these approaches. Other human activities occurred within 500 m of nest marshes, including citrus harvesting and grove maintenance (including pesticide application), cattle ranching, sand and clay mining, farming, a cypress-mulching operation, and human residences. Large trucks carrying sand and liquid cattle feed frequently passed within 200 to 300 m of many nests. Between the 1988 and 1989 nesting seasons, sand mining moved to within 400 m of one marsh where three pairs of cranes continued to nest.

Five of 11 nests within 400 m of a sand mine, an interstate highway, and a railroad were successful. In 1988, one successful nest was only 55 m from I-4. Five pairs of cranes abandoned their nests in marshes less than 370 m from I-4 after major rains in 1988. Up to 120 cranes roosted in the settling basin of a sand mine which was regularly active at night.

Of the 14 nests not visited during incubation, eight hatched, yielding an apparent success rate of 57%. Apparent success rate for visited nests was 73% of 41 nests. Similarly, Mayfield success estimates were 41% for undisturbed nests and 64% for visited nests.

## DISCUSSION

*Nest distribution and chronology.*—The Green Swamp study area supported a relatively large population of Florida Sandhill Cranes, and aerial surveying appeared to be an efficient method for detecting nests (2.5 nests/h) in the swampy habitat. The 1989 surveys, however, were possibly less comprehensive: more nests may have been missed during the seven fixed-wing flights due to the higher speed and altitude (Bishop 1988), and also because of the greater time, up to 16 days, between flights. Yet, we were more familiar with the nesting areas during the second year, so we believe the probability of detecting nests was similar for the two years.

Cranes in the Green Swamp nested earlier than those in the Okefenokee Swamp, Georgia (Bennett and Bennett 1990) and Paynes Prairie, Florida (Nesbitt 1988), but later than those on the Kissimmee Prairie, Florida (Walkinshaw 1976). In general, pairs nesting in smaller marshes, which were used less by migrant Greater Sandhill Cranes, began nesting earlier than pairs residing in the larger (>50 ha) marshes which supported more migrant activity. Perhaps resident pairs in these larger marshes spent more time in territorial defense and other social activities involving the migrant subspecies and thus delayed nesting (Nesbitt, pers. comm.).

*Hatching success.*—Both the Mayfield estimate of 58.8% success and the apparent nest success of 68% are intermediate among those reported for other populations of Florida Sandhill Cranes (Table 3). In general, values from the traditional (i.e., non-Mayfield) method are reported to consistently overestimate success compared to the Mayfield estimates (Hensler and Nichols 1981). Apparent success rates reported in most crane studies are probably biased because a nest can begin and terminate between surveys or searches, resulting in uncounted failed nests. Using radio-telemetered adult cranes, Nesbitt (1988) detected nest initiations earlier and found frequent abandonment soon after initiation in first-time nesters. Thus, his estimates of success probably were less biased.

Predators seem to affect Florida Sandhill Crane nesting less in the Green Swamp than in the Okefenokee Swamp where predators accounted for 75% of all nest failures (Bennett and Bennett 1990). Predation may have been higher in 1989 because of lower water depths in the Green Swamp, permitting greater access to nests in that year. Overall, predation, egg death or infertility, and flooding seemed equally important as sources of nest failure in this study.

Disturbances of any kind that result in an unattended nest can be implicated in such failures as abandonment, predation, and cracked and addled eggs. Although we were unable to determine when an embryo died, it may have been the result of the adult's absence following a nest visit. We were, nonetheless, implicated in at least three nest failures.

*Chick recruitment.*—Nest success is only one component of reproductive success and has little meaning without assessing other reproductive parameters. Flock counts at a local roost did not necessarily represent the reproductive success of the monitored population but served as an index. Recruitment rates based on flock counts may underestimate productivity because they include nonbreeding subadults and not families that remain

TABLE 3

HATCHING SUCCESS RATES OF FLORIDA SANDHILL CRANE NESTS

| Success | N | Location | Reference |
|---|---|---|---|
| 39% | 53 | Paynes Prairie State Park, Florida | Nesbitt 1988 |
| 57% | 187 | Okefenokee Swamp National Wildlife Refuge, Georgia | Bennett and Bennett 1990 |
| 68% | 102 | Green Swamp, Florida | This study |
| 77% | 119 | Kissimmee Prairie, Florida | Walkinshaw 1982 |
| 88% | 25 | Loxahatchee National Wildlife Refuge, Florida | Thompson 1970 |

on their territories, which are less gregarious and often do not roost communally (Bishop 1988). In contrast, monitoring only families may overestimate recruitment (e.g., Layne 1983, Bishop and Collopy 1987).

A stable breeding population of Sandhill Cranes requires a recruitment rate of 10 to 12% (Lovvorn and Kirkpatrick 1982). Low hatching success and even lower recruitment rates (5%) in both years of this study indicated that the local population was relatively unproductive and may be declining. In addition, water levels during 1988 and 1989 seemed favorable relative to drier years, as well as to years with more than one rapid rise in water level. Productivity may be substantially lower or absent in less favorable years. Waskinshaw (1976), Layne (1983), Bishop and Collopy (1987), and Bennett and Bennett (1990) reported recruitment rates of Florida Sandhill Cranes ranging from 6 to 57%.

*Renesting.*—Renesting by Sandhill Crane pairs following the loss of eggs or chicks has been documented for several populations but seems to occur most frequently in southern latitudes, possibly because the nesting season is substantially longer. Bishop (1988) used a 35% (Nesbitt, pers. comm.) proportion to correct/justify the numbers of nesting pairs from her aerial transect sampling to account for the influence of renesting. The incidence of re-nests in the Green Swamp seemed low at 21% but was based on circumstantial evidence since individuals were not marked.

*Human disturbance factors.*—Cranes that nested near I-4 apparently have acclimated to the continuous traffic noise, but how the highway's proximity affected nesting success remains unknown, especially in the long term. The highway may cause adjacent marshes to flood more rapidly. Proximity to an interstate highway seemed to increase chances of flooding through damming of runoff and drainage from impermeable surfaces. All of the five flooded nests were in marshes less than 370 m from I-4. Otherwise, no trends were found relating nest failures to proximity to human disturbance or investigator visits, but several possible cases of human-induced nest failures were documented. Walkinshaw (1976, 1981), Valentine (1982), and Stern et al. (1987) discuss the ability of Sandhill Cranes to reside near human disturbance.

In conclusion, we recommend the following steps to be taken to ensure the survival of the threatened Florida Sandhill Crane: (1) researchers should use the Mayfield method for calculating nest success of sandhill cranes if periodic surveys or searching are employed, and visit nests during cool weather and avoid visiting nests during the laying period, (2) agencies should prohibit the construction of impermeable surfaces near wetlands used by nesting cranes to reduce the chances of flooding, (3) require the increased use of culverts in roads that pass through wetland areas, and (4) require buffer zones adjacent to nest marshes to minimize human disturbance and increase potential brood rearing habitat.

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